www.bsc.es

Reading, 3 July 2017

EC-Earth as a test-bed for climate prediction and services research

Francisco J. Doblas-Reyes
BSC Earth Sciences Department and ICREA

BSC Earth Sciences Department

What

Environmental forecasting

Why

Our strength …

research
operations
services
more than 60 people working together

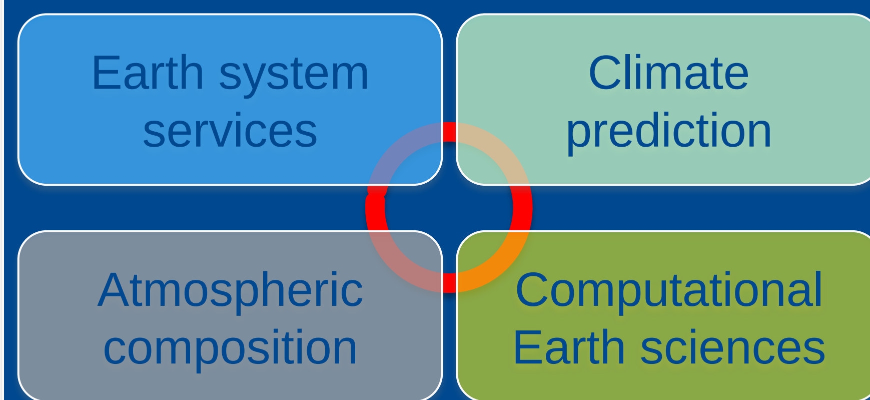
How

Develop a capability to model air quality processes from urban to global and the impacts on weather, health and ecosystems

Implement a climate prediction system for subseasonal-to-decadal climate prediction

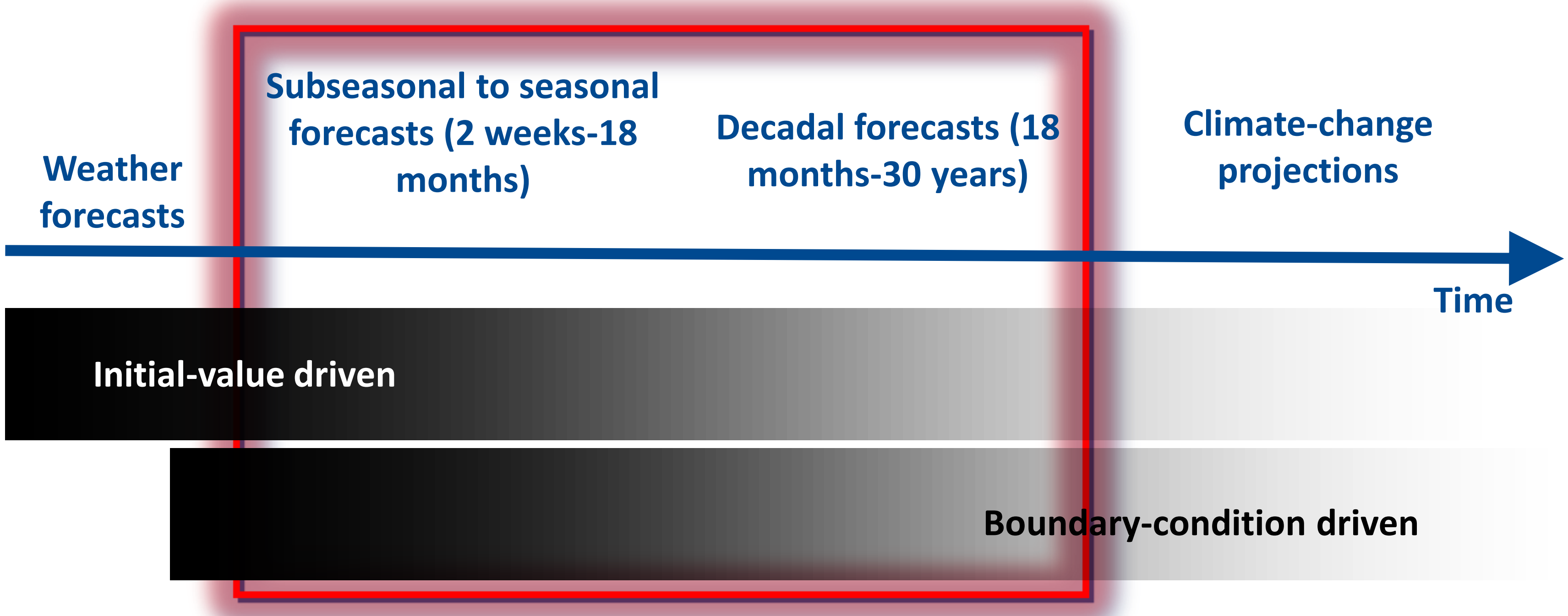
Develop user-oriented services that favour both technology transfer and adaptation

Use cutting-edge HPC and Big Data technologies for the efficiency and user-friendliness of Earth system models



Climate prediction time scales

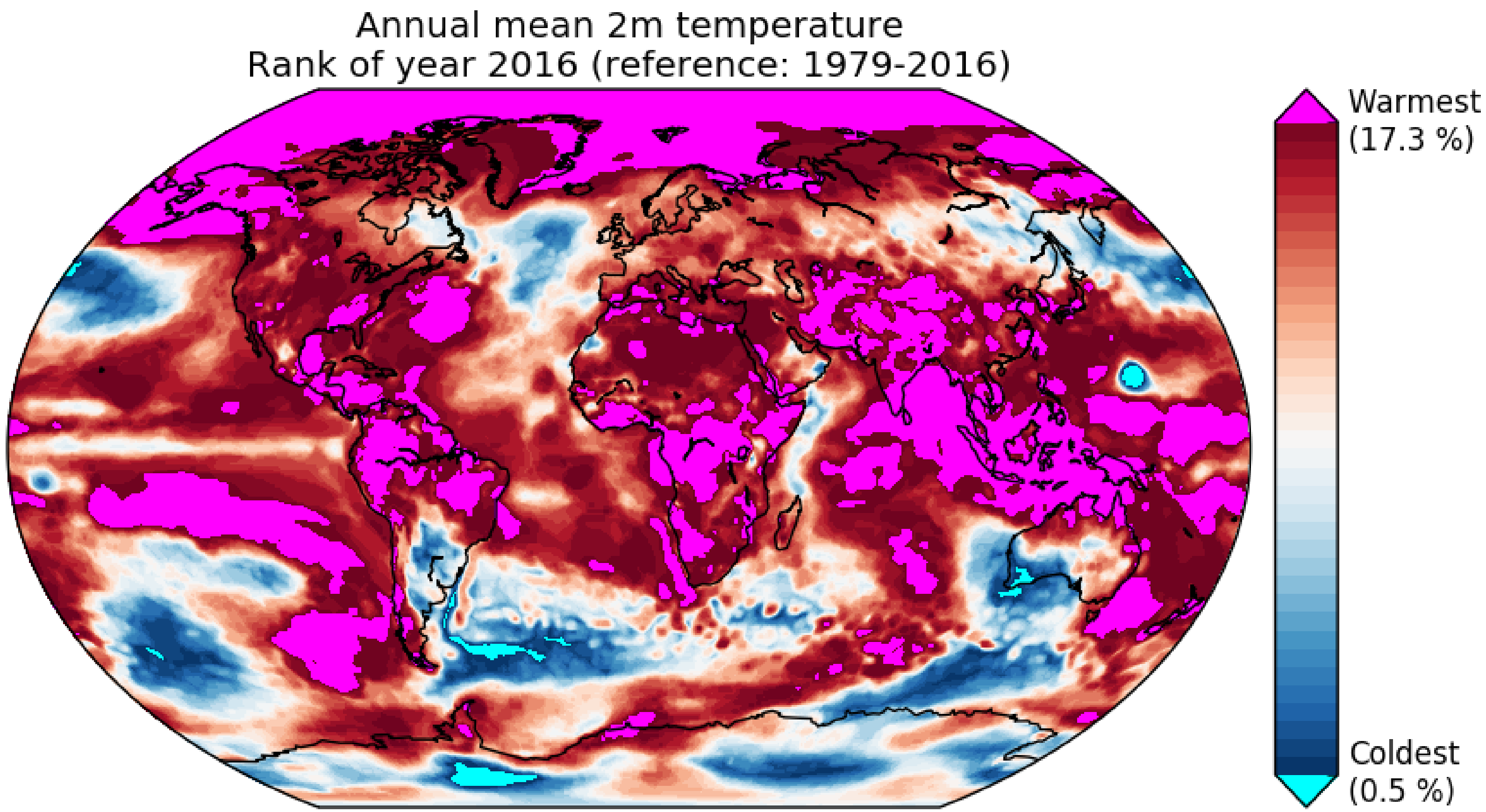
Progression from initial-value problems with weather forecasting at one end and multi-decadal to century projections as a forced boundary condition problem at the other, with climate prediction (sub-seasonal, seasonal and decadal) in the middle. Prediction involves initialization and validation/verification.



Adapted from Meehl et al. (2009)

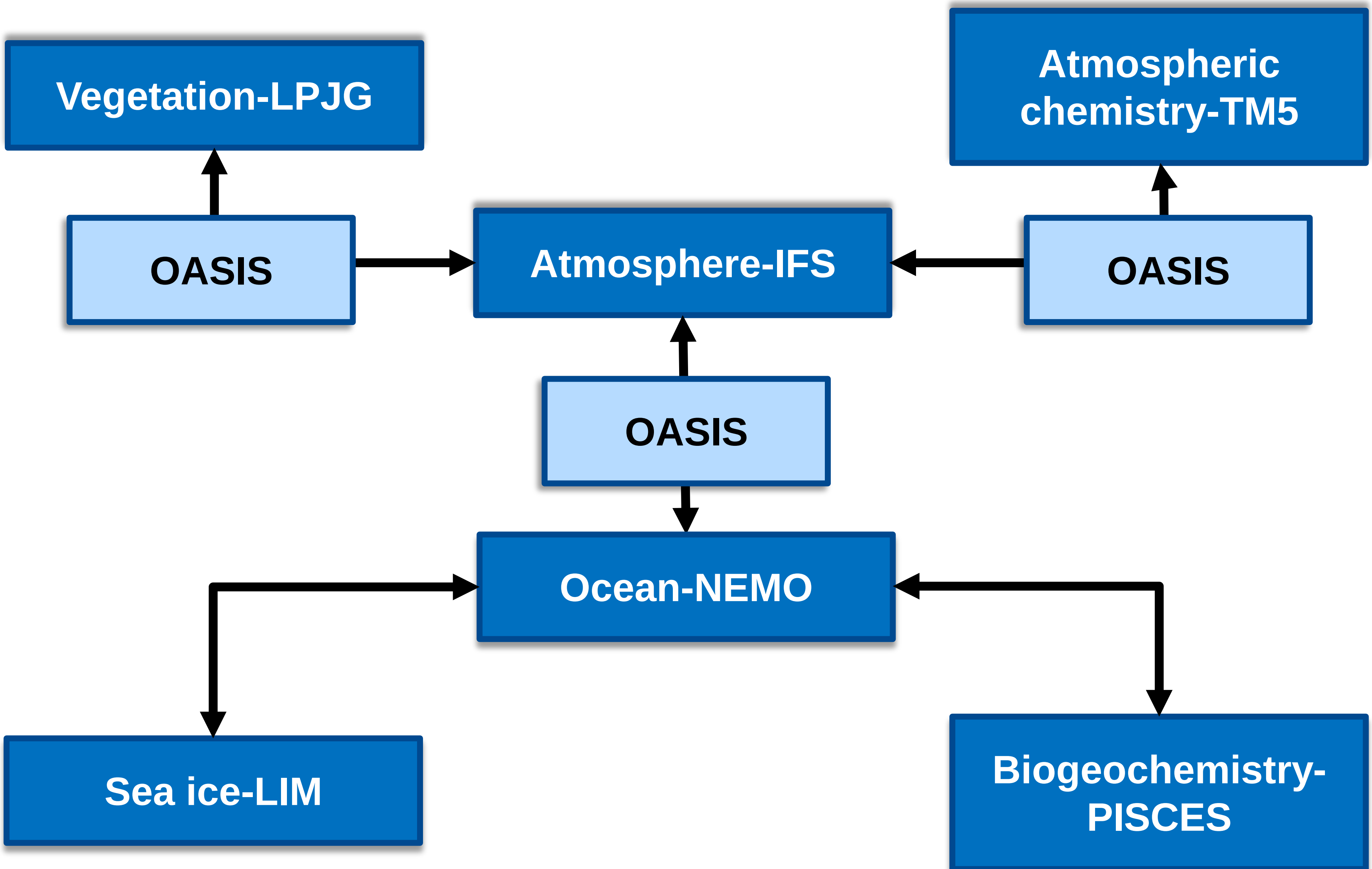
The type of signal to be predicted

Ranking of the 2016 annual mean temperature over the last 37 years from ERA Interim.



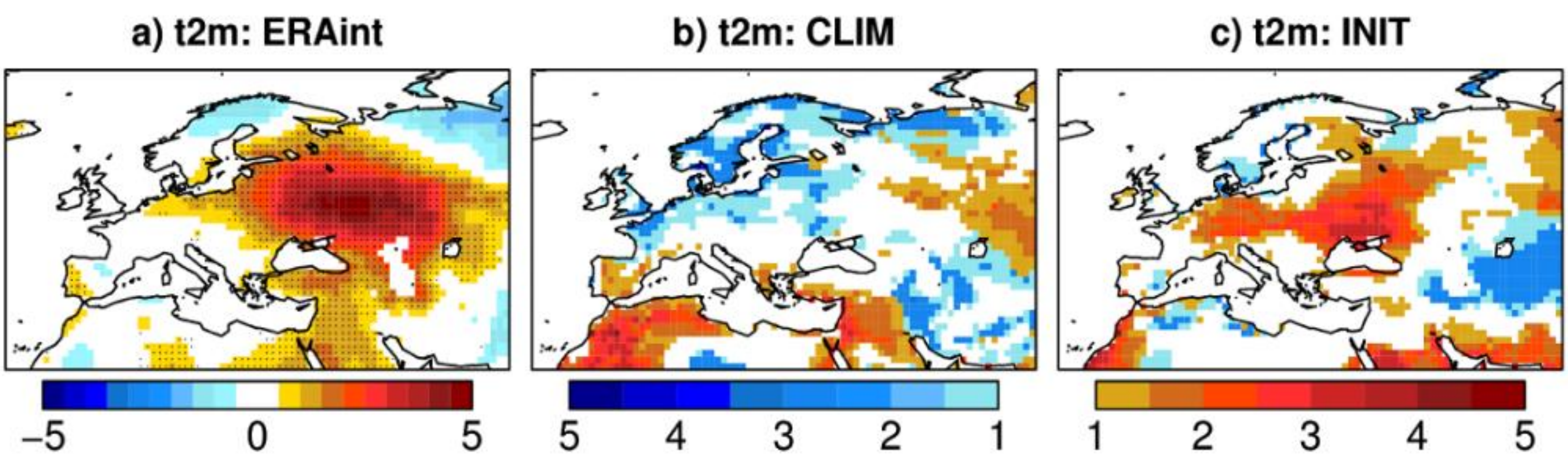
Data: ERA-Interim. Figure: F. Massonnet - BSC

The Earth system model: EC-Earth



Skill and land-surface initialisation

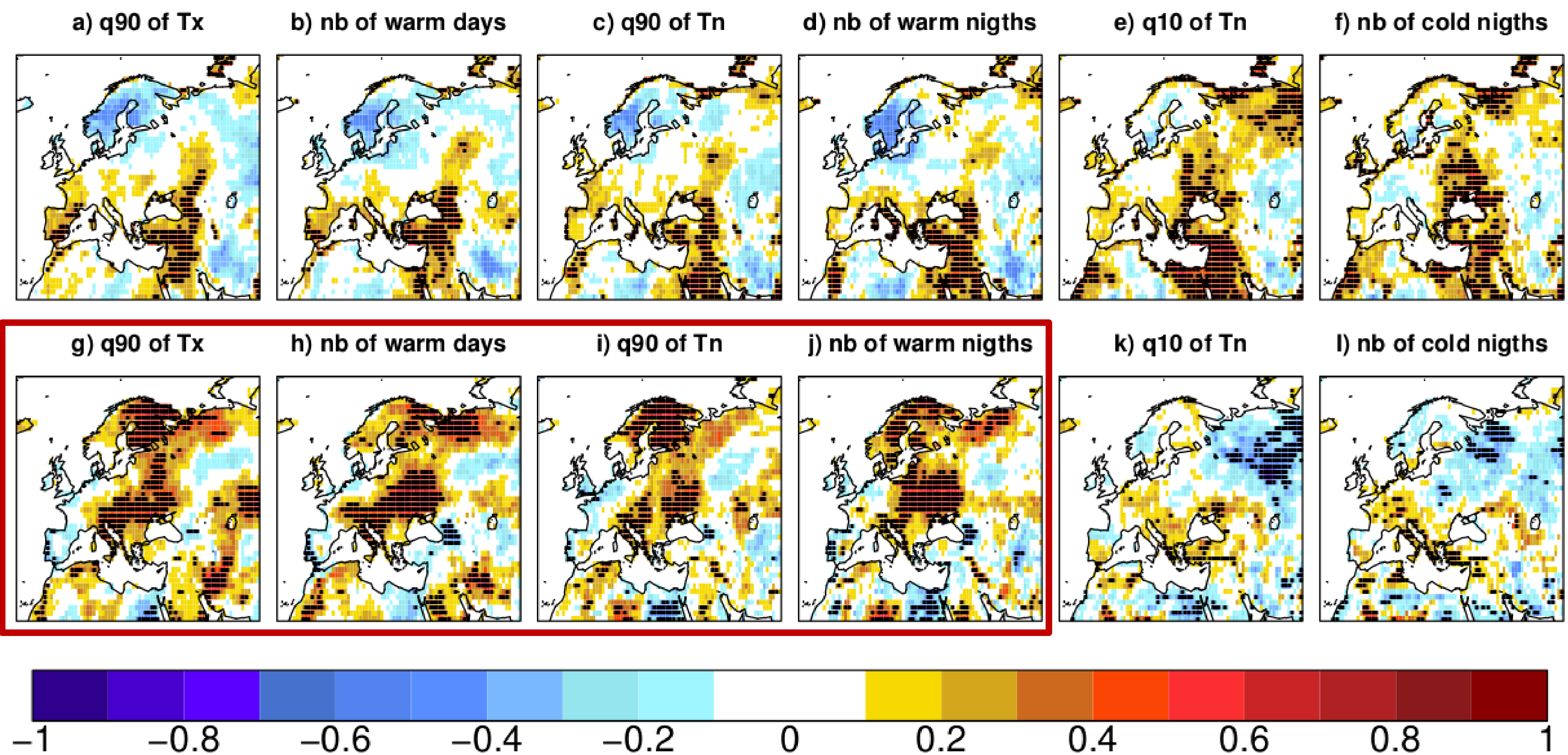
JJA near-surface temperature anomalies in 2010 from ERAInt (left) and odds ratio from experiments with a climatological (centre) and a realistic (right) land-surface initialisation. Results for EC-Earth2.3 started in May with initial conditions from ERAInt, ORAS4 and a sea-ice reconstruction over 1979-2010.



Prodhomme et al. (2015, Clim. Dyn.)

Skill and land-surface initialisation

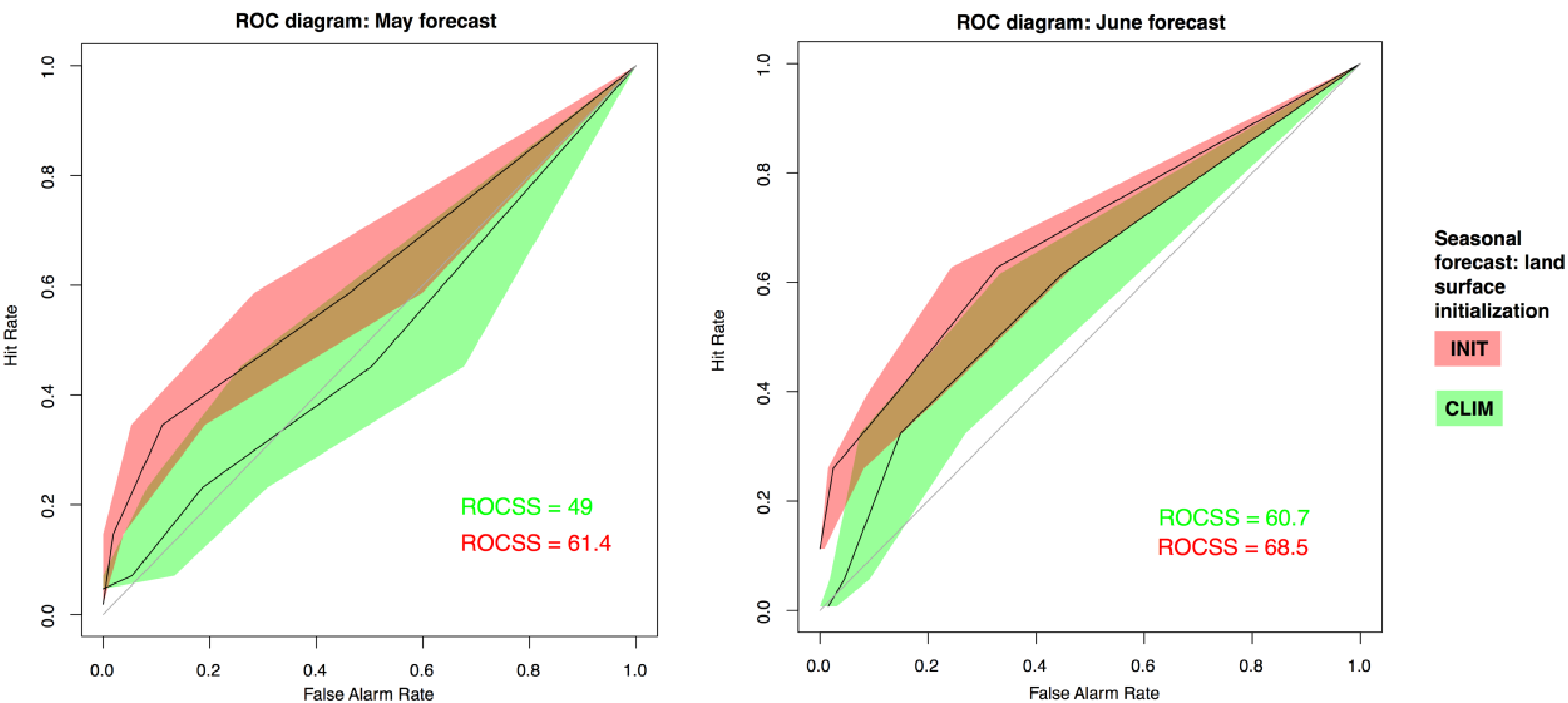
JJA near-surface temperature correlation of the ensemble mean from experiments with a climatological (top) and difference with one with realistic (bottom) land-surface initialisation. Results for EC-Earth2.3 started in May over 1979-2010.



Prodhomme et al. (2015, Clim. Dyn.)

Users and system improvement

ROC diagram of predictions of poor maize yield (lower quartile) from EC-Earth seasonal predictions when land-surface is initialised with realistic (INIT) and climatological (CLIM) initial conditions with May and June start dates.



Ceglar et al. (submitted to NCC)

Users and system improvement

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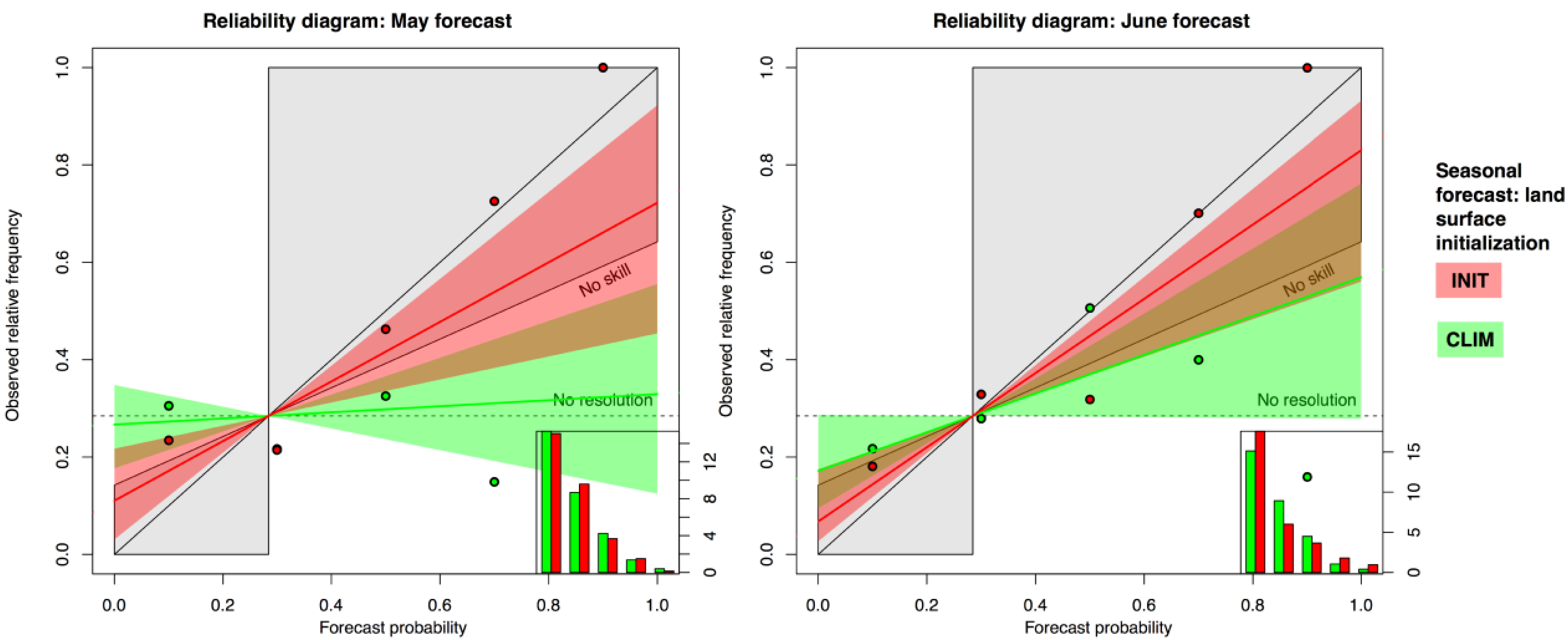
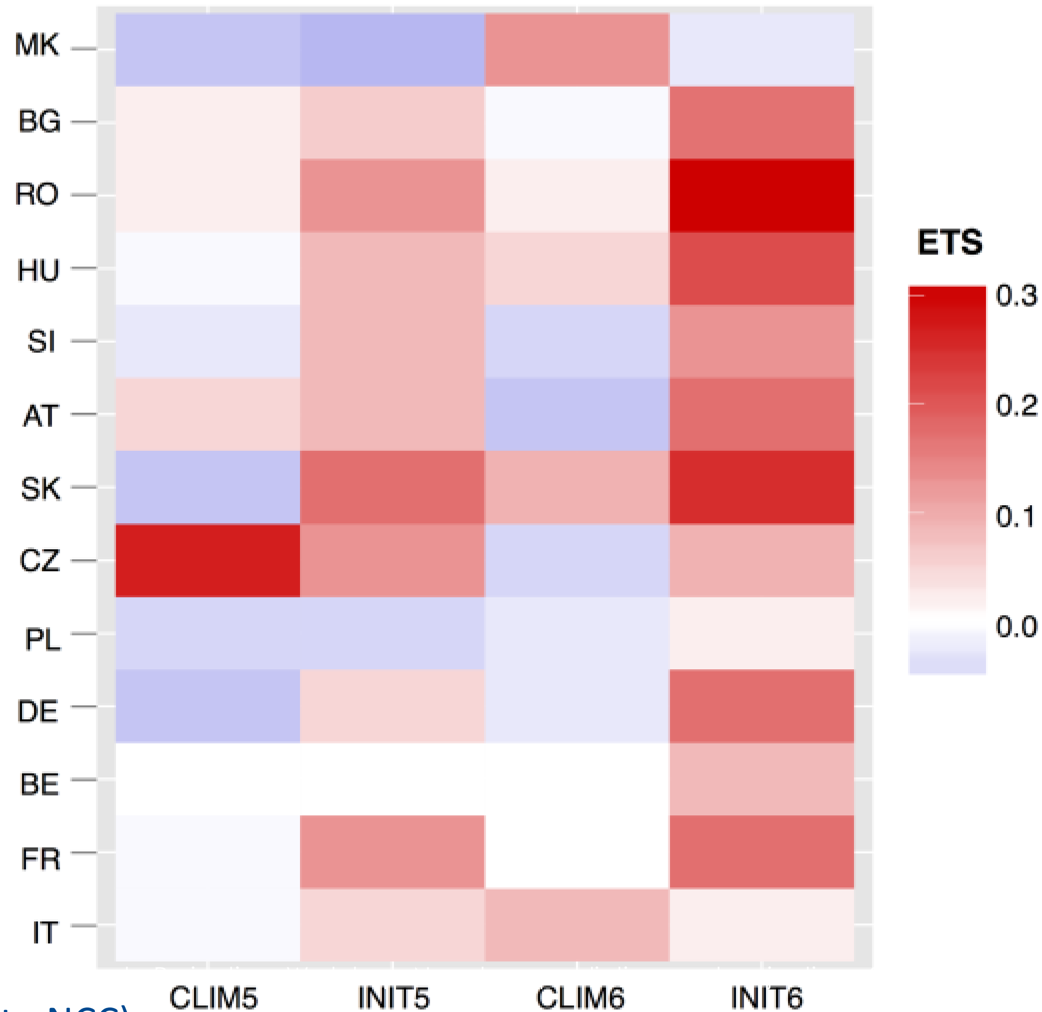


Ceglar et al. (submitted to NCC)

Users and system improvement

Equitable threat score (ETS) of predictions of poor maize yield (lower quartile) from EC-Earth seasonal predictions when land-surface is initialised with realistic initial conditions (INIT) wrt no information (CLIM).

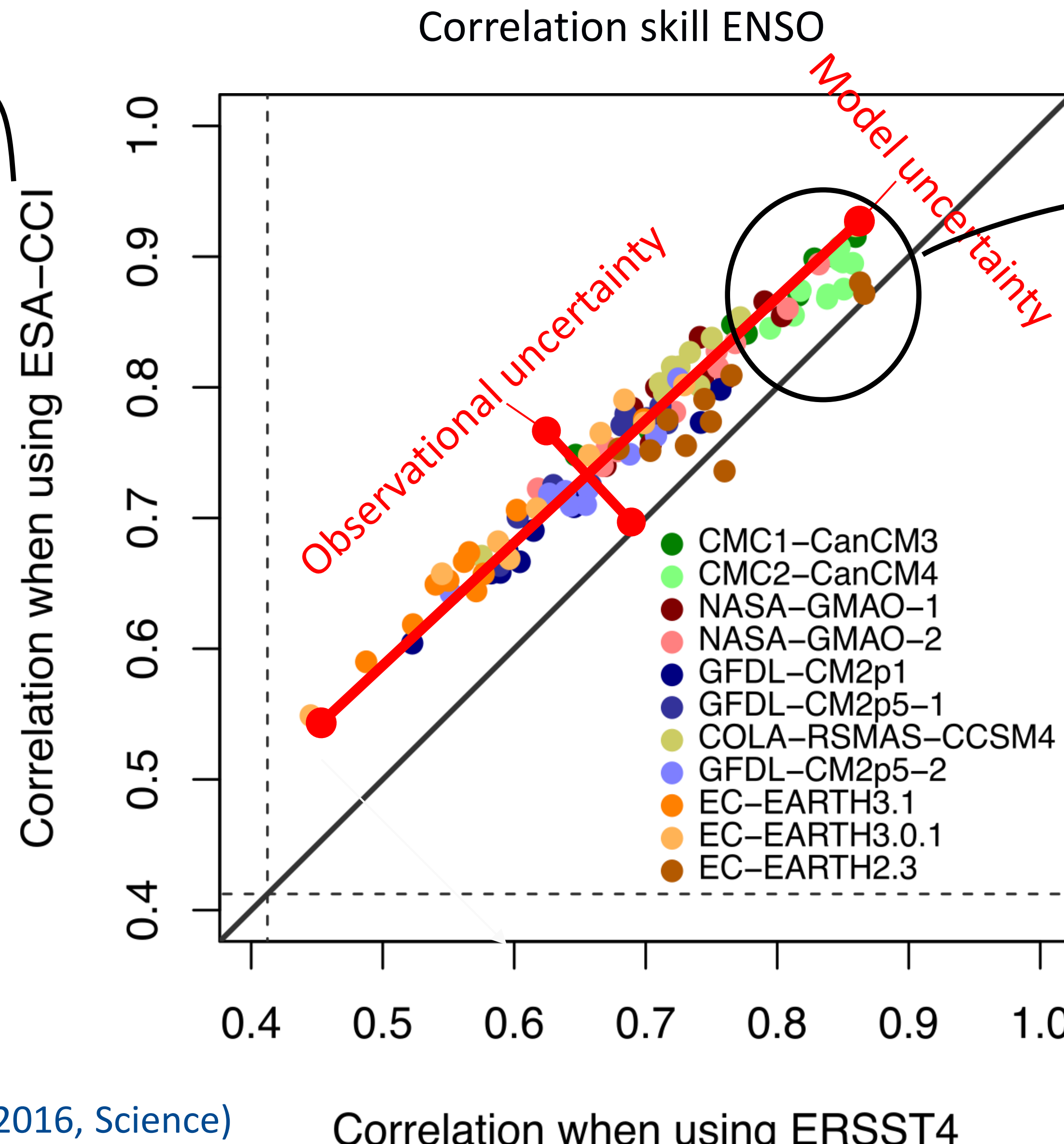


Ceglar et al. (submitted to NCC)

Model and observation uncertainty

Models can also be used to estimate the quality of observational estimates.

Independent from the models

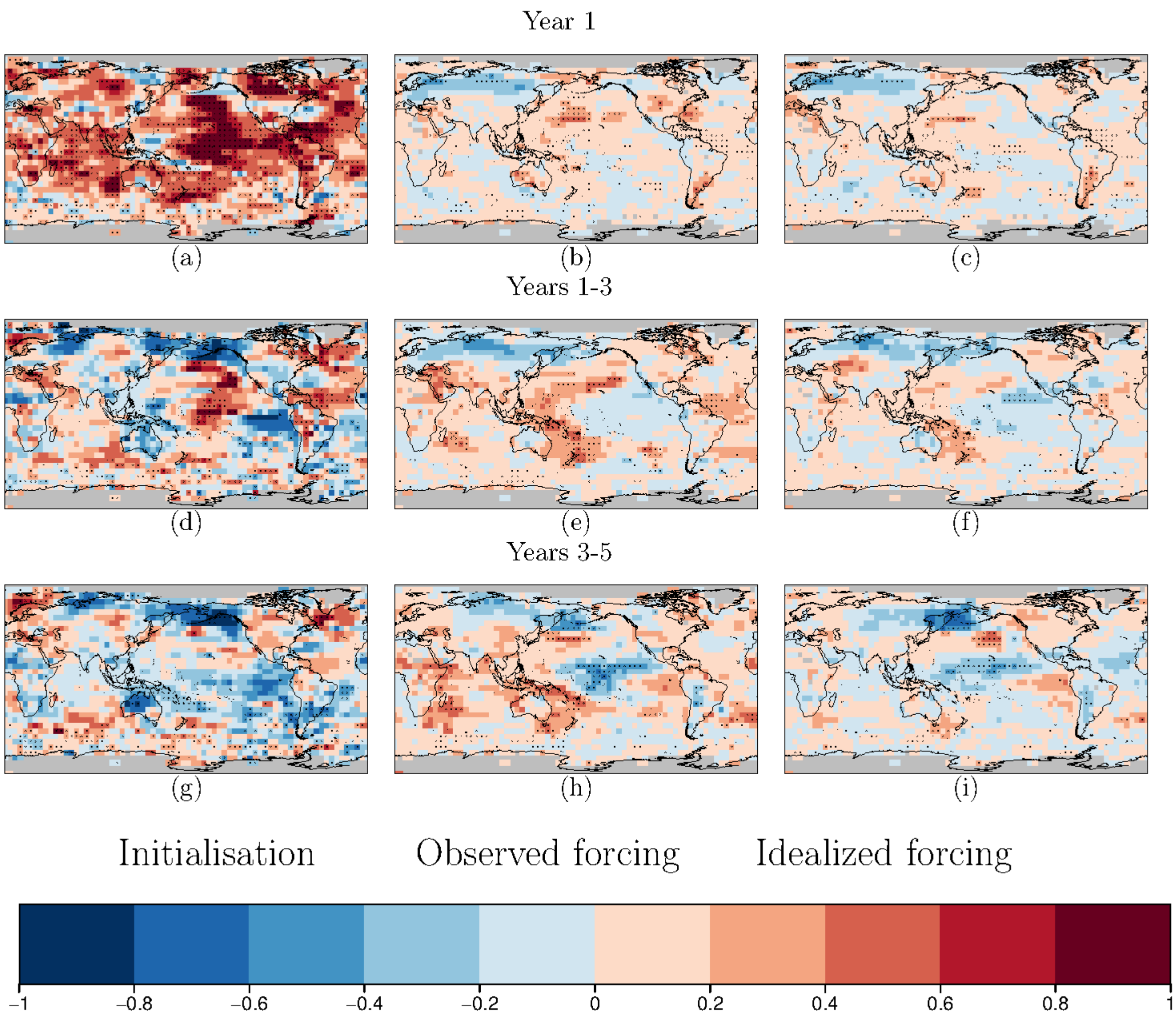


How important for individual systems?

Massonnet et al. (2016, Science)

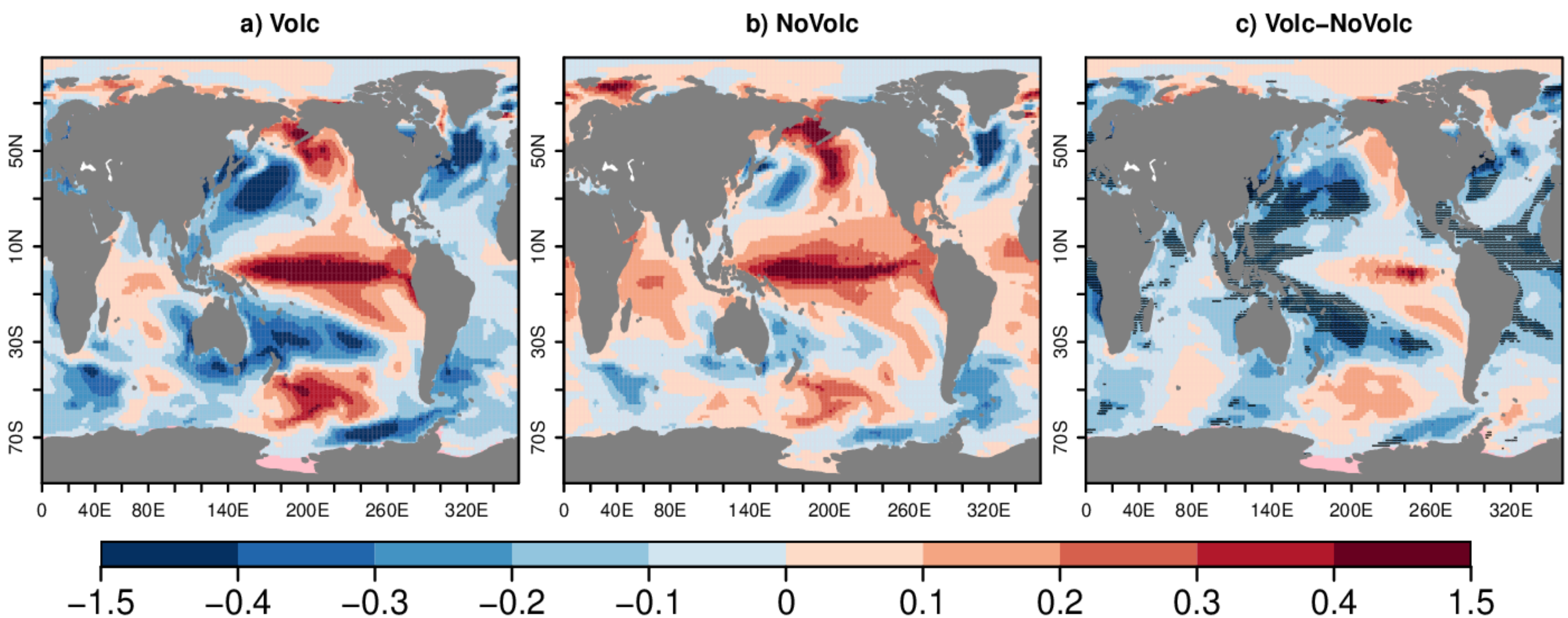
Impact of volcanic aerosol

Impact of the initialisation and two types of volcanic forcing in the correlation of the ensemble mean of the EC-Earth2.3 decadal predictions.



Impact of volcanic aerosol

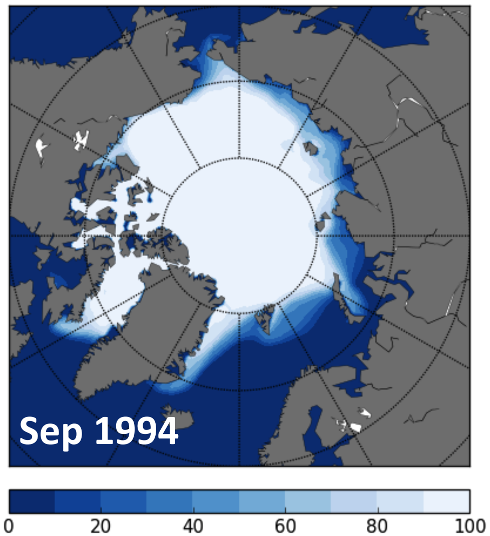
Mean SST anomaly (K) the first forecast year following the Agung (1963), El Chichon (1982) and Pinatubo (1991) eruptions in EC-Earth2.3 decadal hindcasts a) including the volcanic forcing (Volc), b) not including the volcanic forcing (NoVolc) and c) the difference (Volc-NoVolc). Stipling for differences statistically significant at 95% level.



M. Ménégoz, R. Bilbao

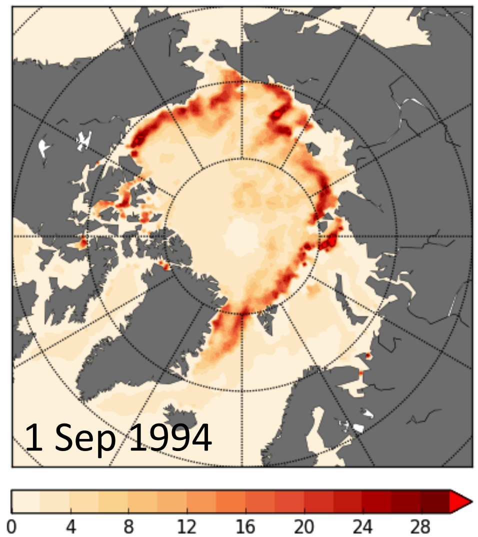
Sea-ice reanalysis

25-member EnKF analysis (one-month window) with EC-Earth3.2 where ESA-CCI concentration data are assimilated.

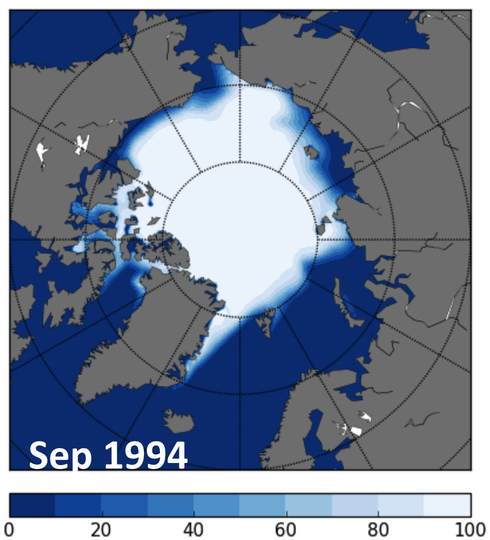


Free-running **EC-Earth3.2**

Ensemble mean SIC

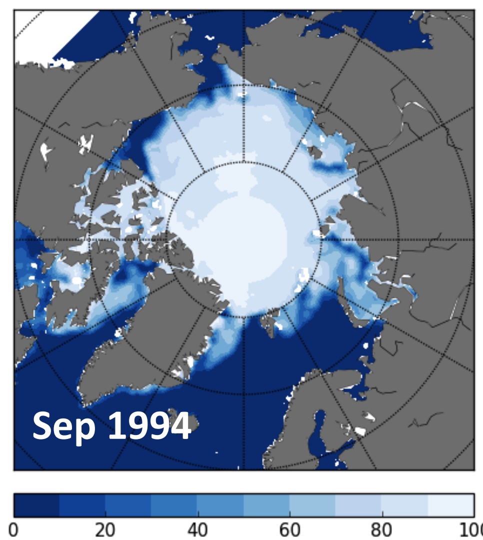


ESA CCI SIC uncertainty



EnKF (SIC) **EC-Earth3.2**

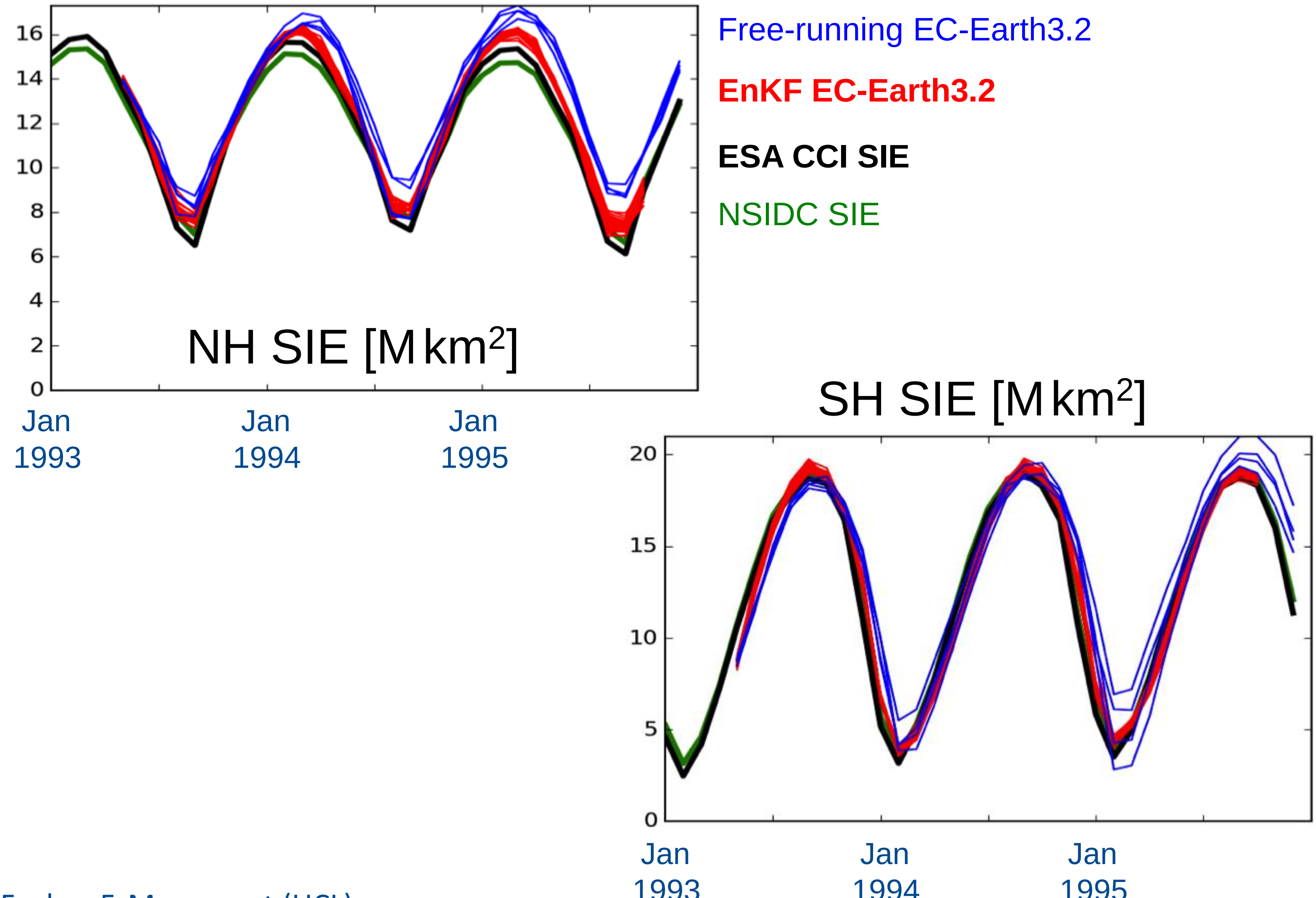
Ensemble mean SIC



NSIDC SIC

N. Fuckar, F. Massonnet (UCL)

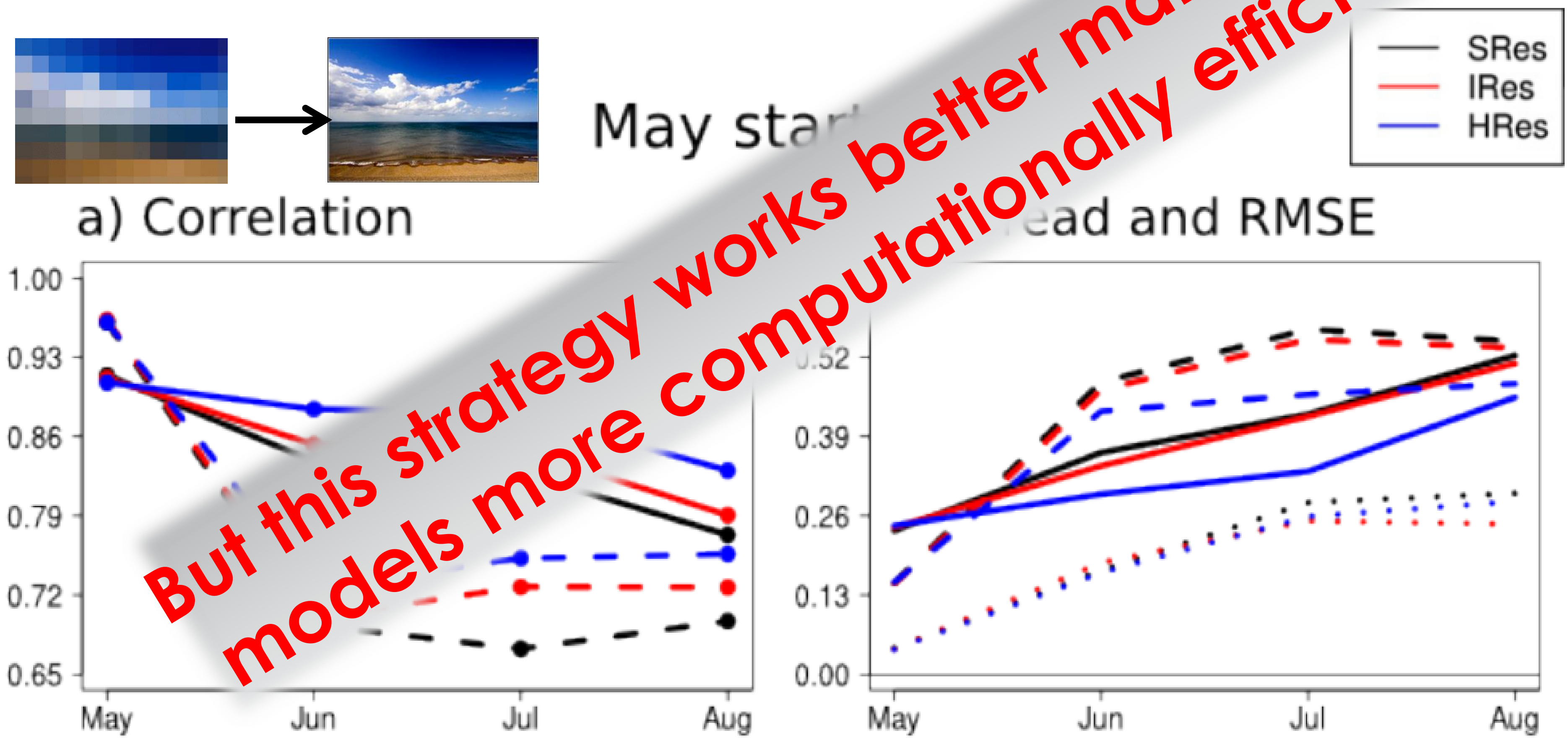
Sea-ice reanalysis



N. Fuckar, F. Massonnet (UCL)

Effect of increasing the resolution

Forecast quality from EC-Earth3.1 seasonal hindcasts (1993-2009, Glorys2v1, ERAInt and ERALand initial conditions). Solid for ESA-CCI and dashed for ERSST. Blue for high resolution ocean and atmosph[...] red for high resolution ocean, black for standard resolution.



But this strategy works better making the models more computationally efficient

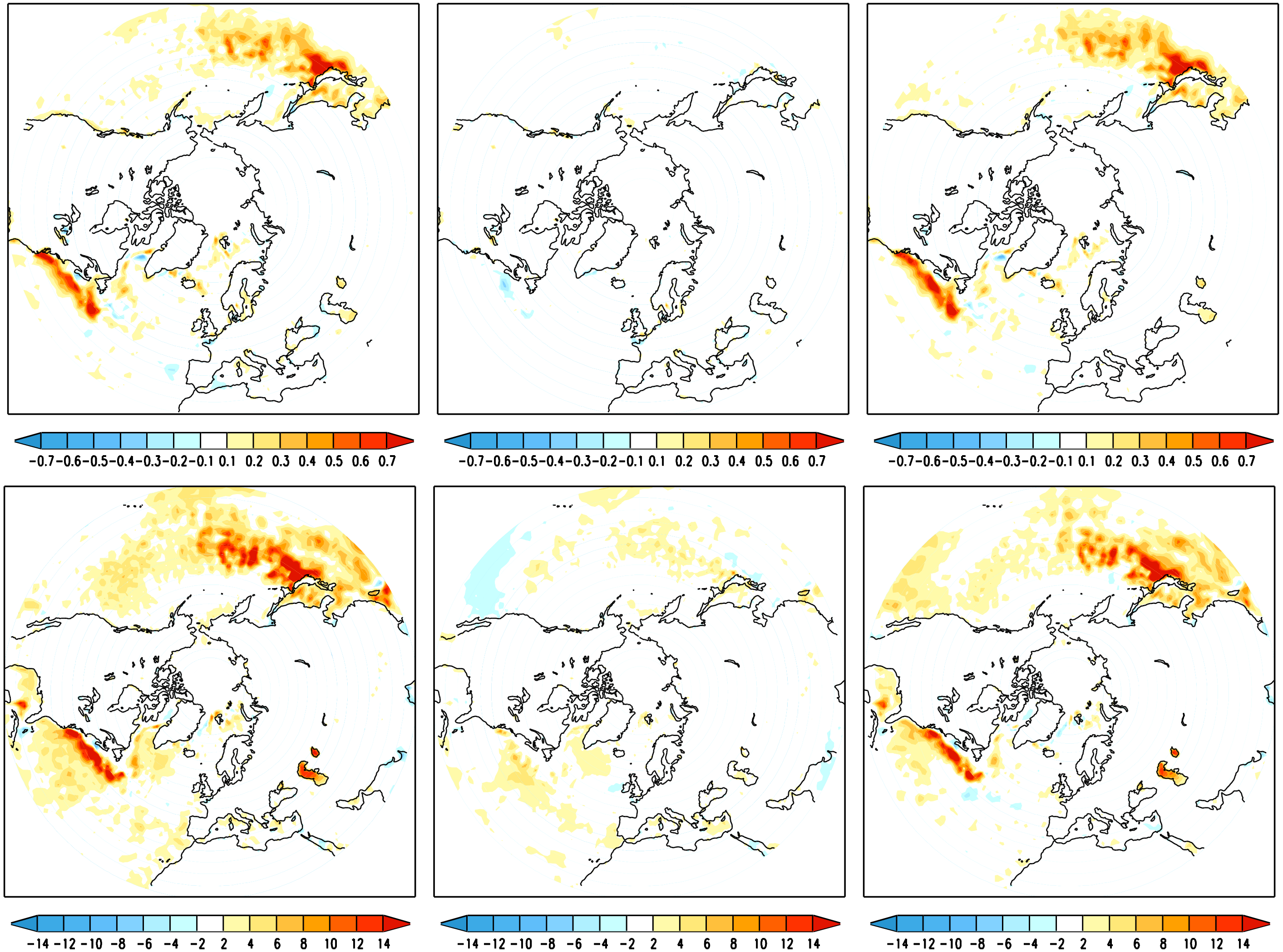
Prodhomme et al. (2016, J. Climate)

Effect of increasing the resolution

Differences of interannual variability of winter mean variables from the EC-Earth3.1 hindcasts at different resolutions.

SST

LHF



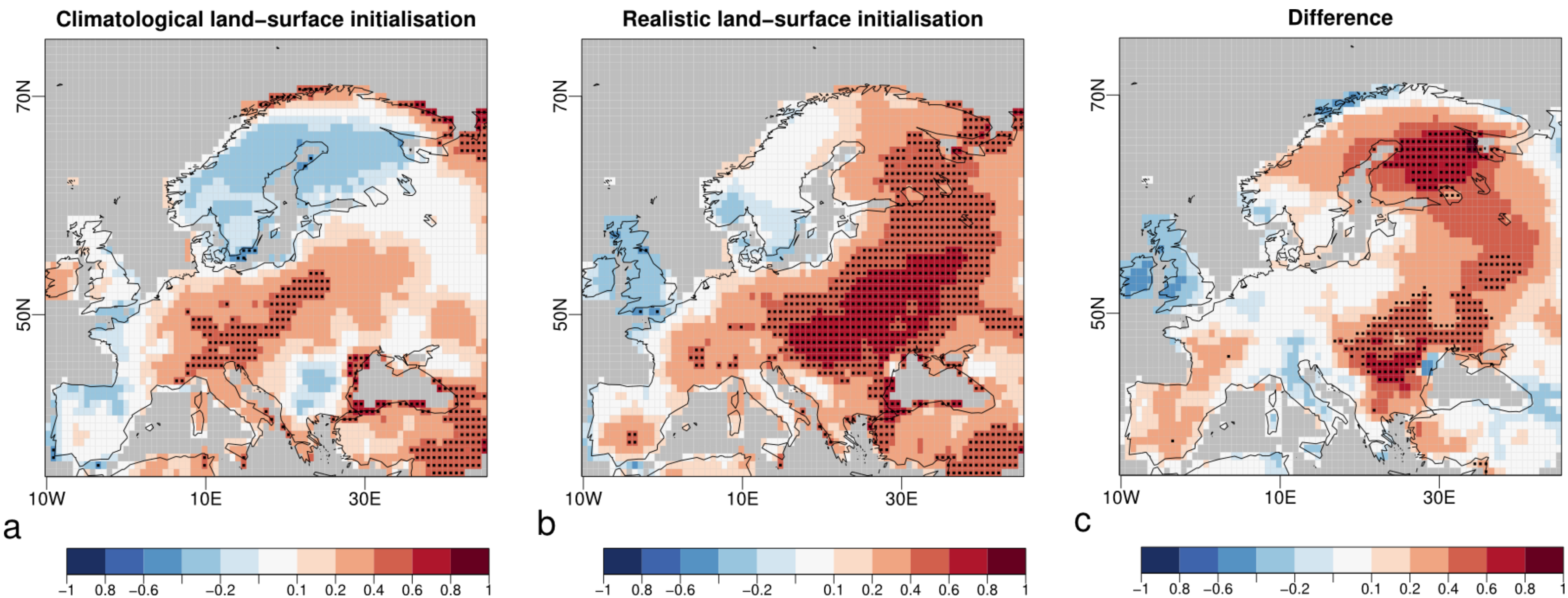
↑Oc↑At-↓Oc↓At **↑Oc↑At-↑Oc↓At** **↑Oc↓At-↓Oc↓At**

R. Harsma

Is the impact of HR significant?

Correlation of JJA near-surface temperature from EC-Earth3.1 hindcasts started in May over 1993-2009 with climatological (left) and ERA-Land (centre) land-surface initial conditions, and their difference (right).

Hard to detect differences in sensitivity experiments: use of the Steiger test for correlation differences (increased power).



Siegert et al. (2017, MWR)

Drift and systematic error

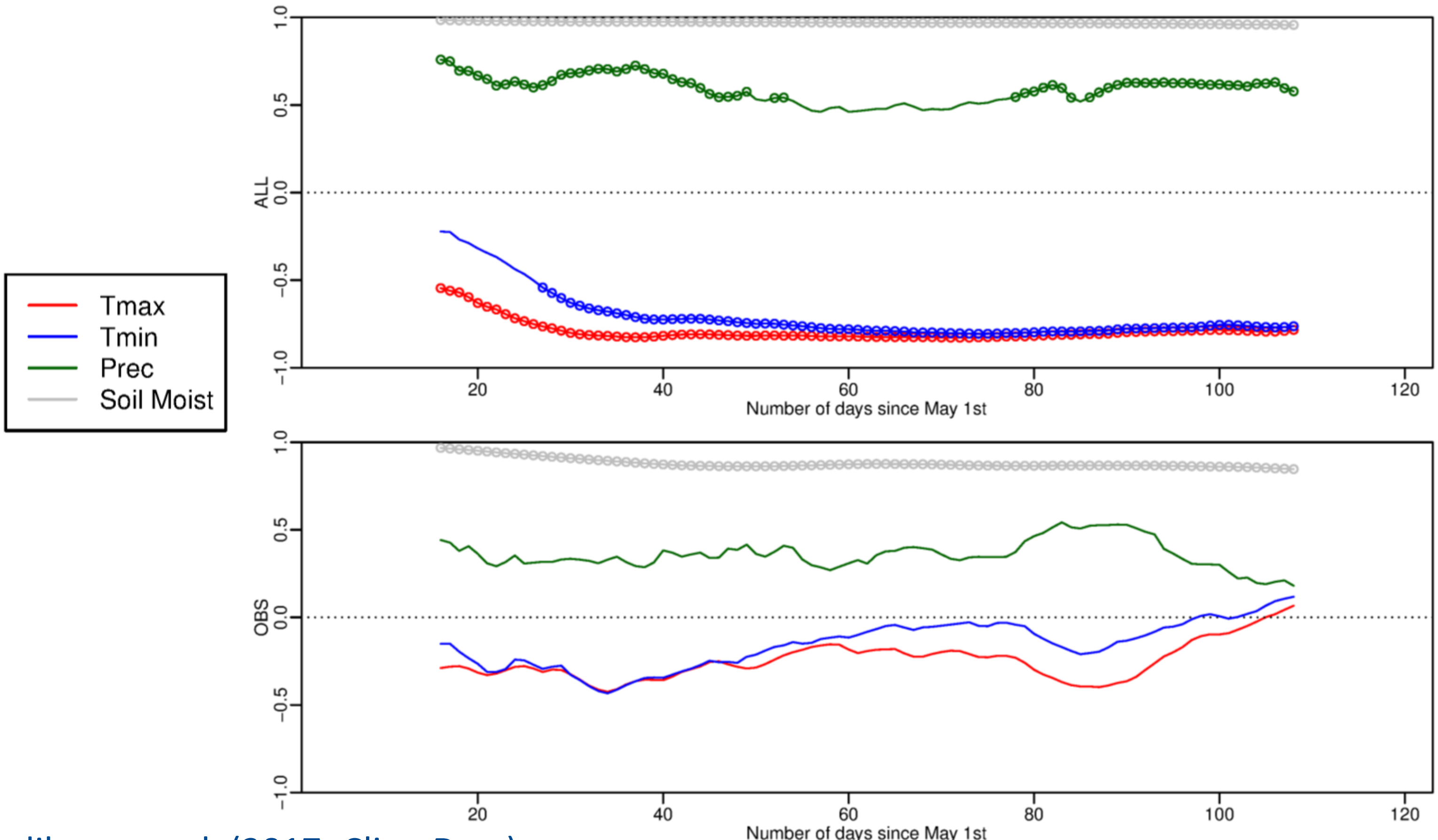
- The previous work is based on forecast and observed anomalies, without full consideration of the climate characteristics.
- Forecast anomalies are computed as differences from a model climatology. Observational reference anomalies use an observational climatology for the same period.
- The model climatology is different for each start date because the model drifts from the initial conditions based on observations towards the model stationary climate.
- In this context, systematic errors are a moving target.
- The characteristics of the drift depend on the variable considered and can be either very fast (SLP, days) or very slow (ocean salinity, decades).
- The stationary systematic errors (those analysed in the CMIP exercises) are not necessarily relevant for climate predictions.

Drift uses: uncovering model errors

Barcelona Supercomputing Center
Centro Nacional de Supercomputación
EXCELENCIA SEVERO OCHOA

Correlation between 1st of May total soil water content and 31-day running mean of variables from the SPECS multi-model seasonal forecast (top) and ERAInt (bottom) over North American Great Plains.

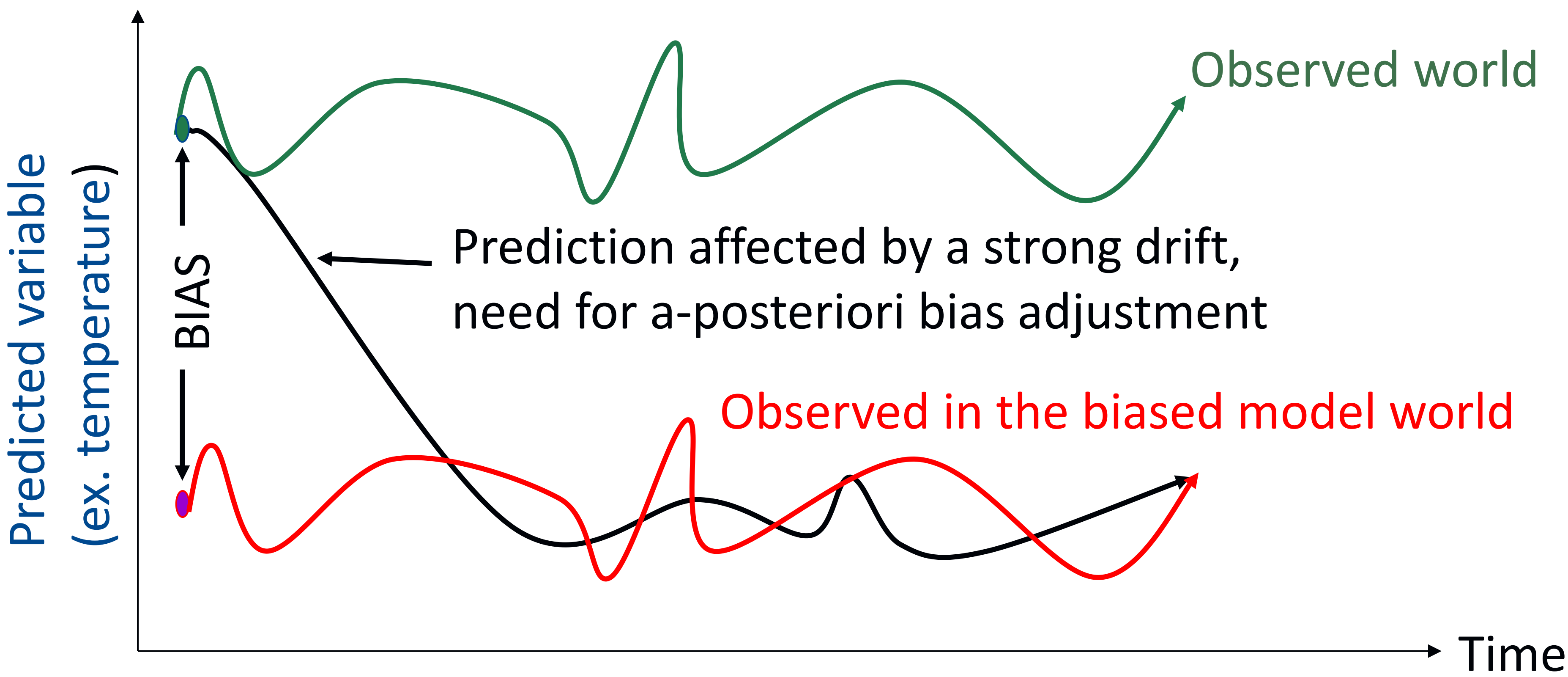
The model shifts quickly to excessive land-atmosphere coupled state.



Ardilouze et al. (2017, Clim. Dyn.)

A potential solution: anomaly initialisation

Up to now all the examples used full-field initialisation.

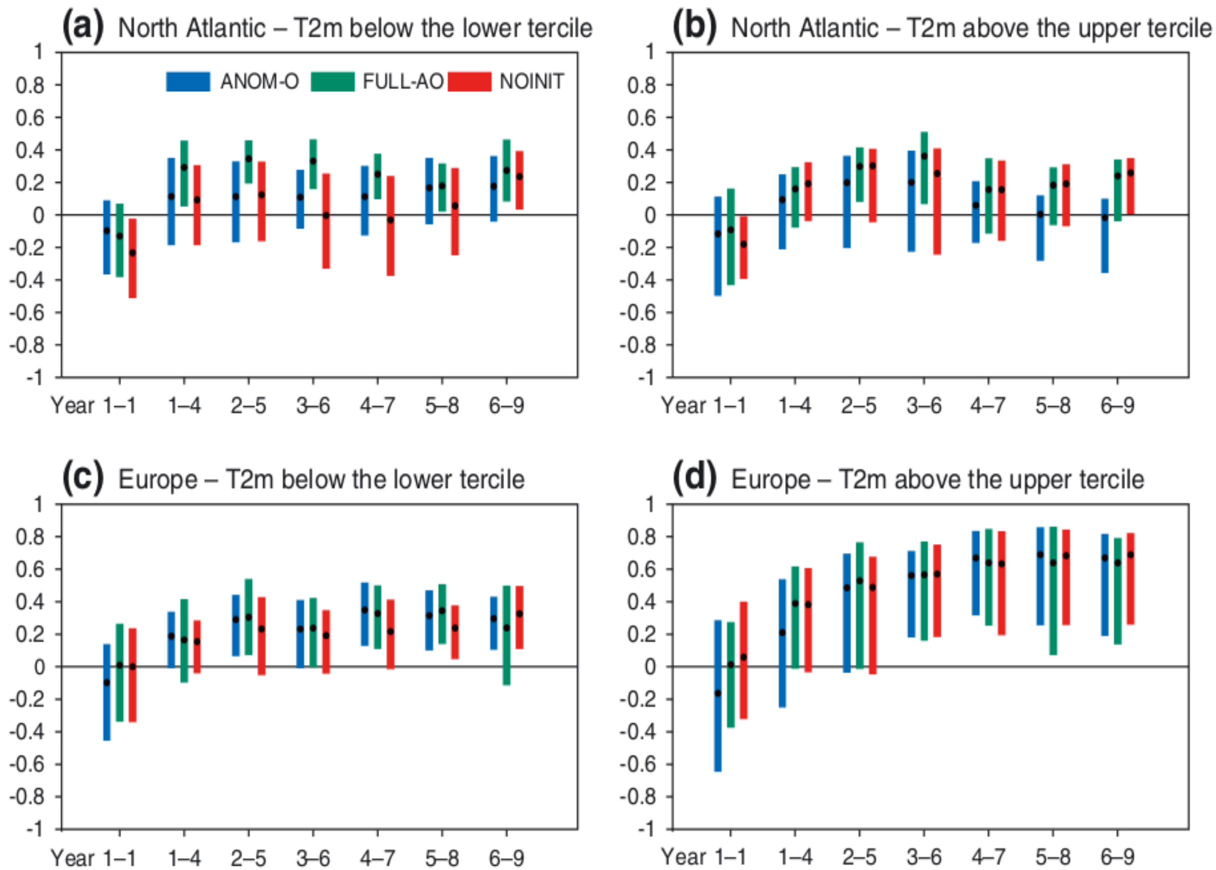


A prediction can also be formulated with anomaly initialisation: start from the observations imposed on an estimate of the model climate.

Alternatives are flux correction and anomaly coupled.

Anomaly and full-field initialisation

Brier skill score of near-surface temperature for EC-Earth2.3 over (a,b) North Atlantic (30ºN-87.5ºN), (c,d) Europe (35ºN-75ºN; 12.5ºW-42.5ºE; land only) for events (a,c) below lower and (b,d) above upper tercile as a function of forecast time. Bars for the 95% confidence interval. Red: NoInit, blue: anomaly init, green: full-field init.



Hazeleger et al. (2013, GRL)

Validation and verification packages

Developments from SPECS and EUPORIAS. Tried to solve some of the problems identified in the generic "verification" R package. Similar coordinated initiatives are taking place with ESMValTool.

SCORES

SpecsVerification (University of Exeter)
- Probabilistic and deterministic scores
- Works on [time x members] arrays

easyVerification (MeteoSwiss)
- Applies SpecsVerification scores to arrays of any dimensions, multi-core
- Probabilistic and deterministic scores

FRAMEWORKS

downscaleR + loadeR (Universidad de Cantabria, CSIC)
- Data retrieval and homogenization
- Bias adjustment, modes, downscaling
- Probabilistic and deterministic scores
- Visualisation of data and results

s2dverification (BSC)
- Data retrieval and homogenization
- Bias adjustment, filtering, modes
- Probabilistic and deterministic scores
- Visualisation of data and results

The multi-model real-time decadal prediction exchange is a research exercise that guarantees equal ownership to the contributors.

WMO-CCl will operationalise this activity.

Multi-model decadal forecast exchange

The Met Office coordinates an informal exchange of near-real time decadal predictions. Many institutions around the world are developing decadal prediction capability and this informal exchange is intended to facilitate research and collaboration on the topic.

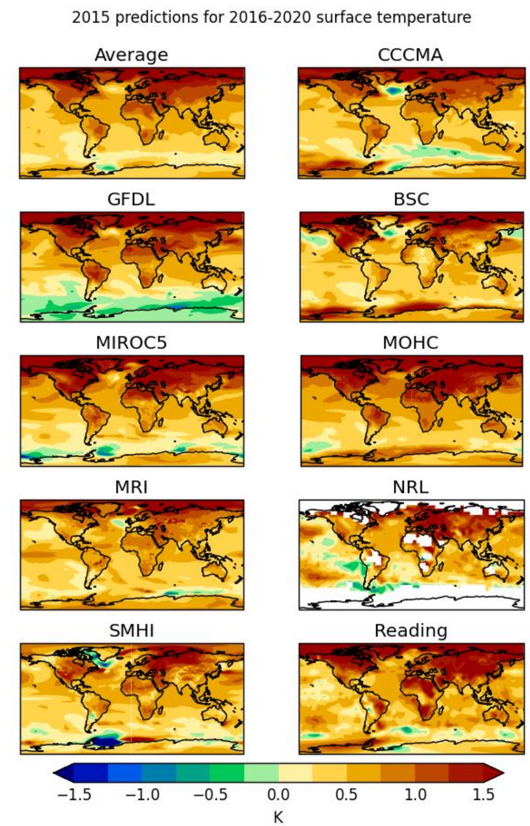
The contributing prediction systems are a mixture of dynamical and statistical methods. The prediction from each institute is shown below, alongside an average of all the models. When possible, observations for the period of the forecast are also shown. Currently three variables are included: surface air temperature, sea-level pressure and precipitation. These are shown as differences from the 1971-2000 baseline. More diagnostics, including ocean variables are planned for the future. Please use the drop-down menus below to explore the data collected to date.

This work is supported by the European Commission SPECS project.

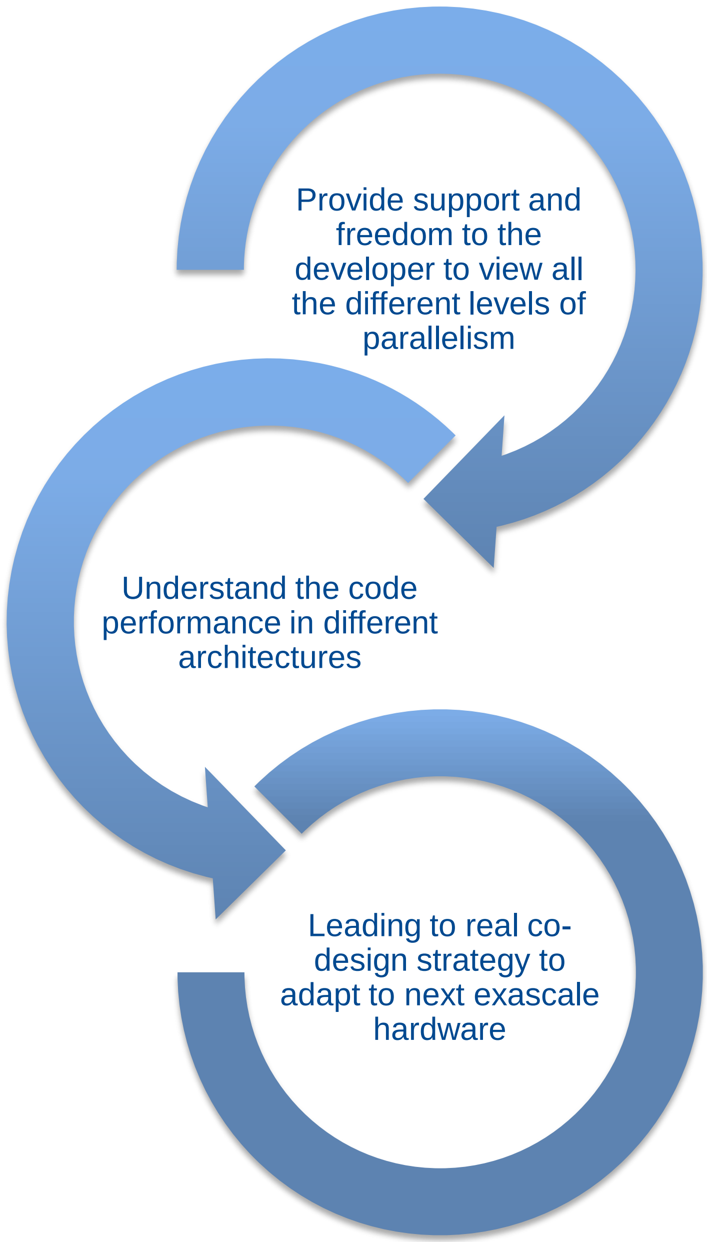
To learn more about decadal forecasts at the Met Office, see our current decadal forecast.

Images last updated 2014-06-25

Issued	Period	Element
2013	year 1	surface air temperature



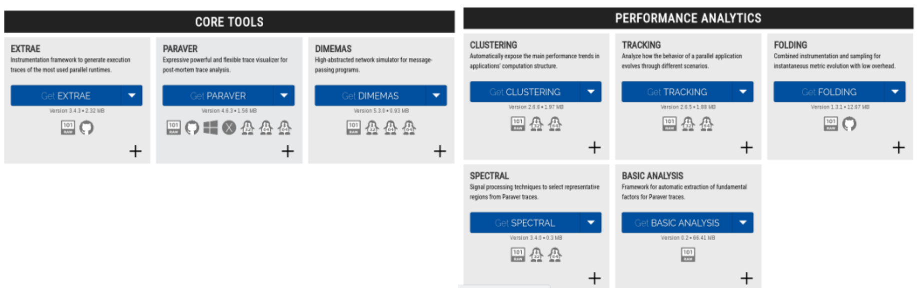
Computational performance



Improving NEMO's performance

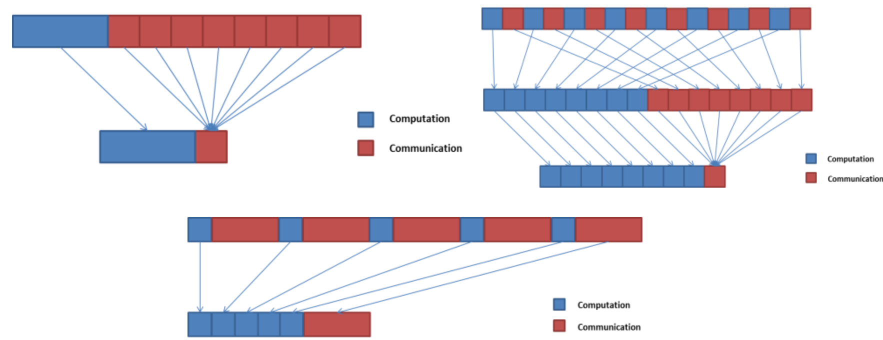
Collaboration with computer sciences department

BSC performance tools



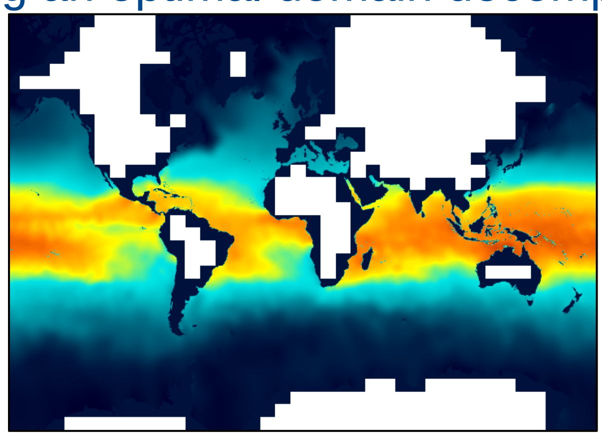
MPI communications optimizations

Reducing p2p and collective communications overhead



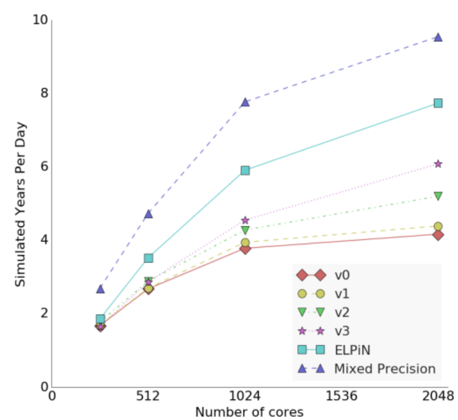
Exclude land processes in NEMO

Finding an optimal domain decomposition



Explore mixed precision

Which precision is needed in NEMO?



Potential overall improvement:

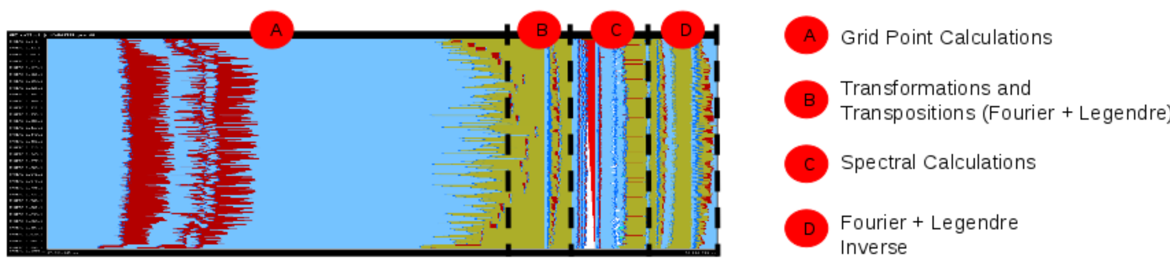
2x

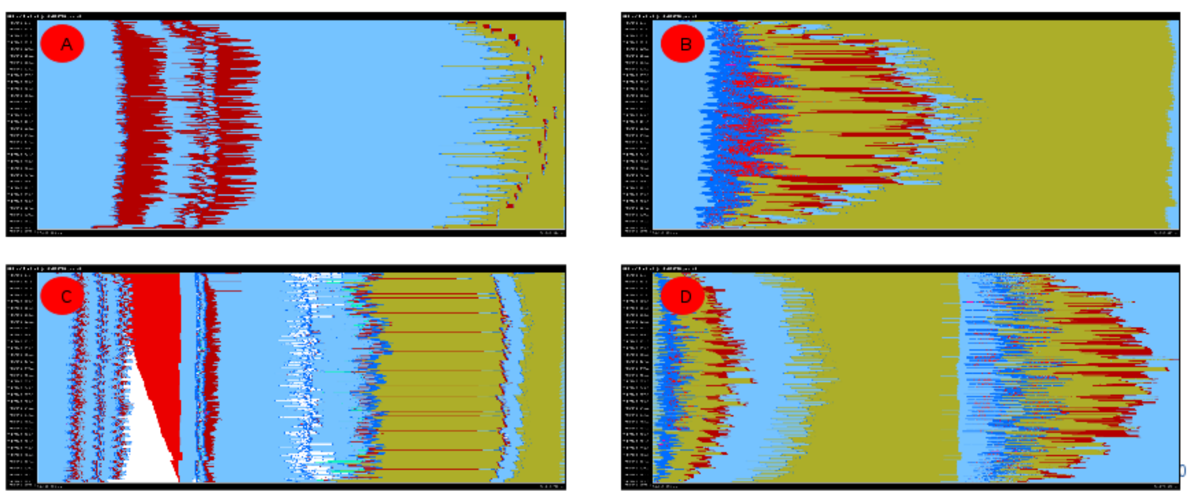
M. Castrillo, O. Tintó, M. Acosta, K. Serradell

Relevance to ECMWF

ECMWF researchers will be able to use the BSC performance tools in the next IFS release

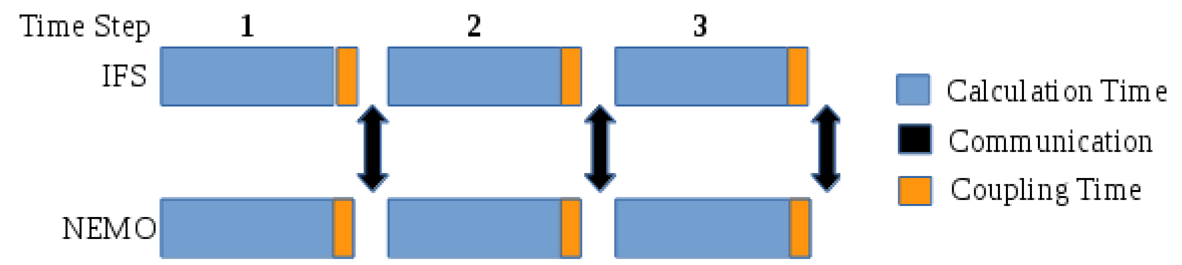
- Now available using nama_CY43R1_IFS_traces branch (also tested with OpenIFS CY40R1)
- This will be possible activating BSCTRACE from PrepIFS
- Tutorials and user guides for IFS in development by C. Simarro and M. Acosta



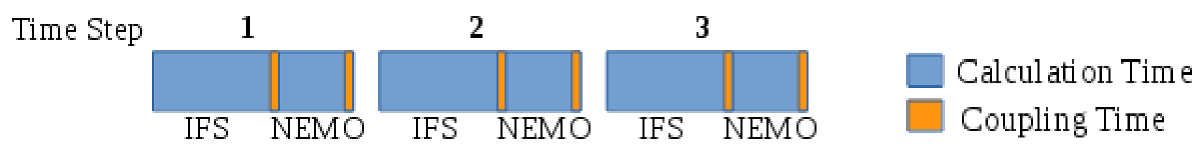


Plans for computing performance

- Work together to evaluate the advantages and disadvantages of IFS/NEMO coupling



Independent components

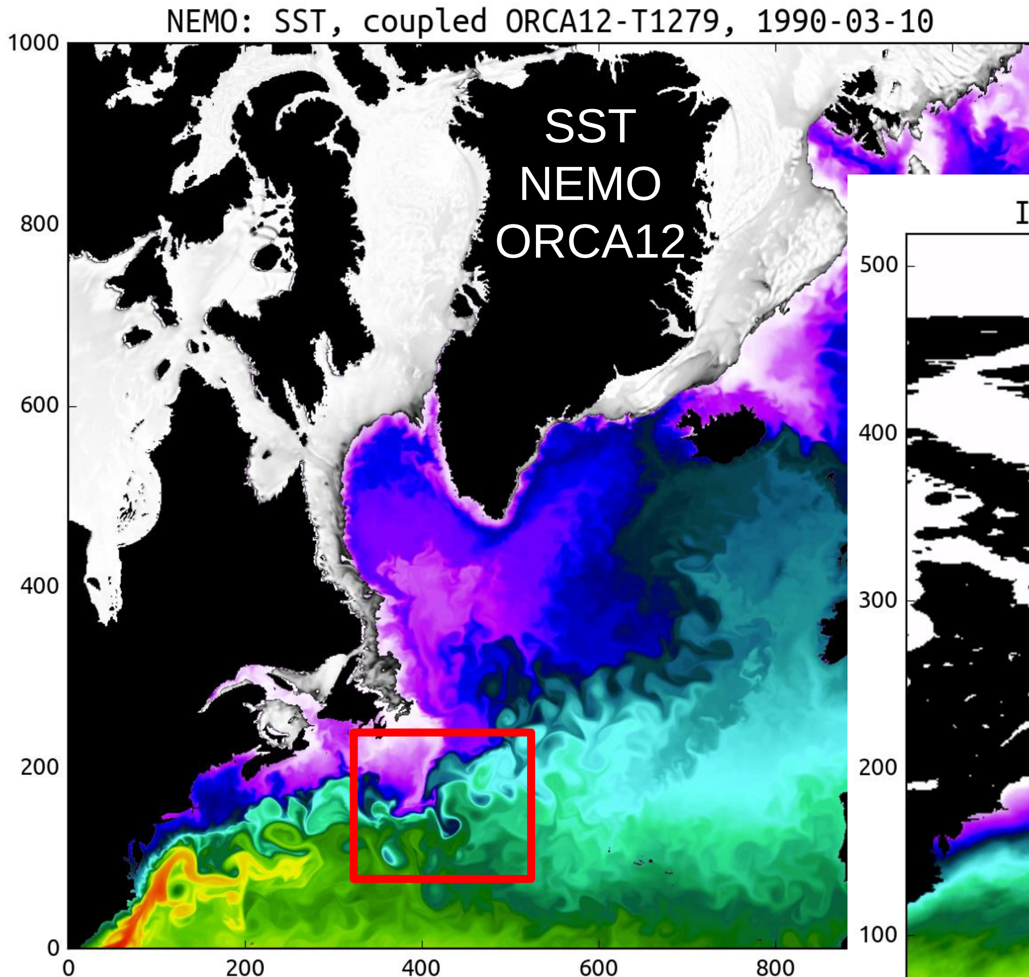


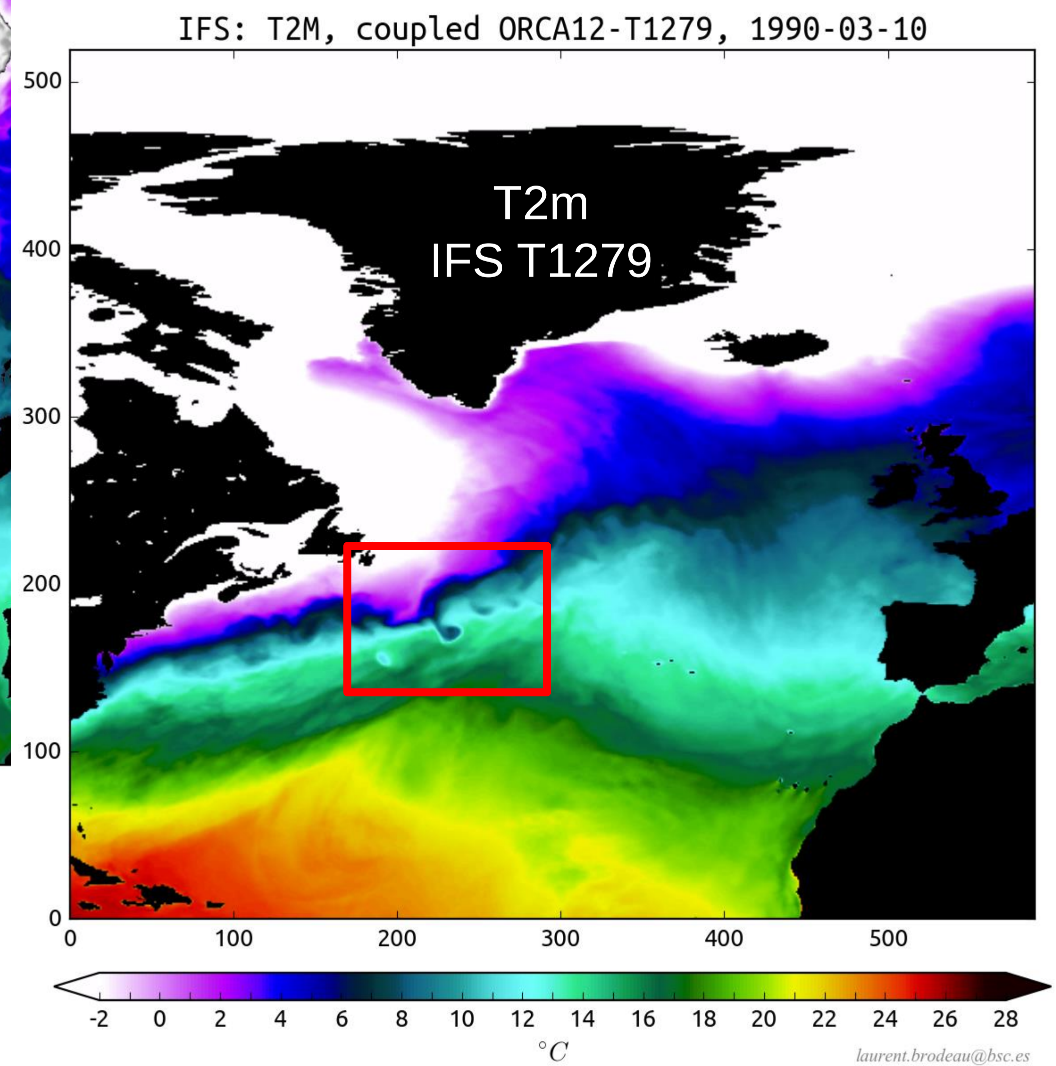
Using a single binary

- Work on the OpenIFS 43R1 as soon as it is released.
- Implement XIOS in OpenIFS (collaboration with eScience Center).
- Port OpenIFS to ARM (Cavium ThunderX).
- Implement the Dynamic Load Balancing library to reduce the code unbalance.

High-resolution global modelling

EC-Earth GLOBAL ORCA12-T1279
(ocean and atmosphere at ~15 km!)

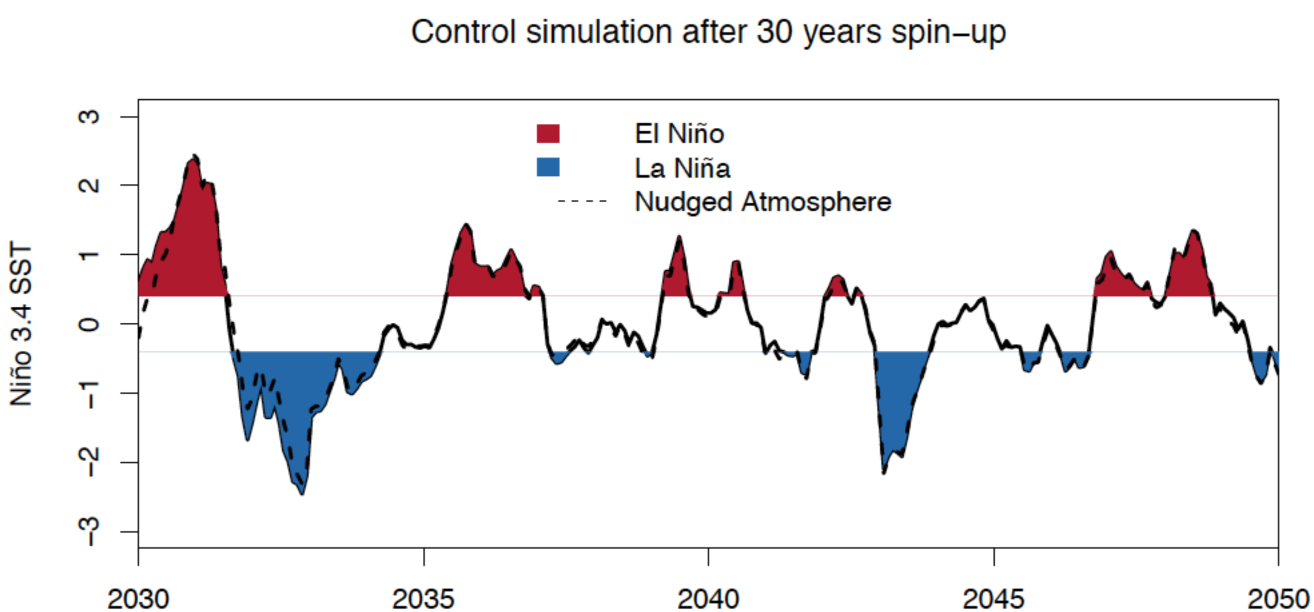




Extreme event attribution

Removing the forced climate response in the initial state to allow simultaneous prediction and attribution of extreme climate events. Needs large ensembles and a methodology to remove the forced response.

The nudging of the atmospheric circulation from a control simulation creates similar ENSO variability even when starting from a different ocean state.

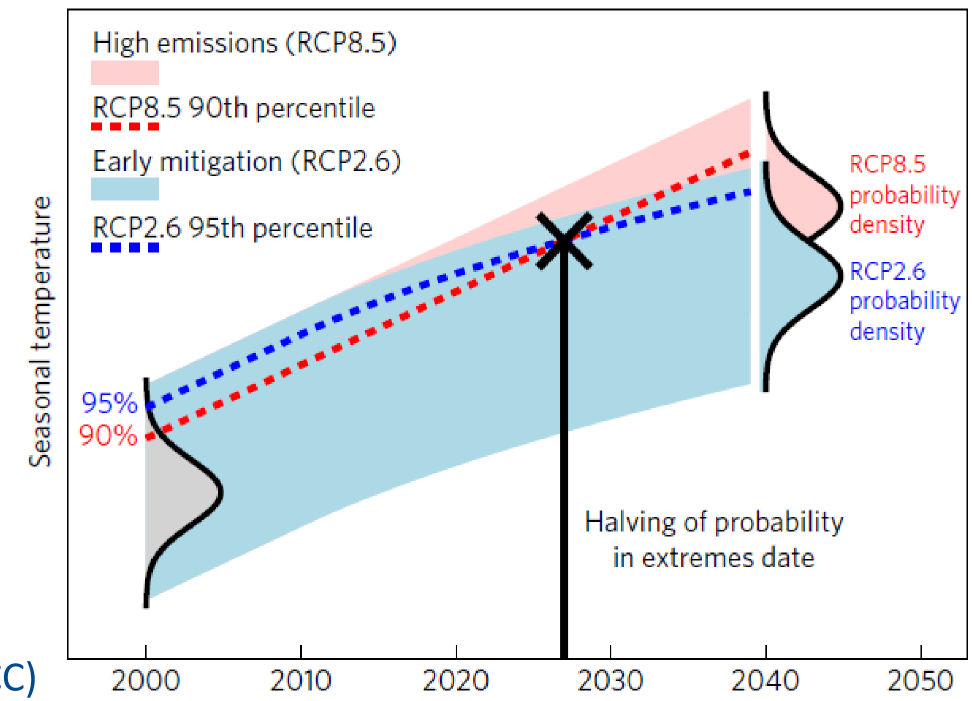


O. Bellprat

Attribution and global stocktake

Simulate short-term ocean carbon uptake to assess mitigation efficiency. Needs to consider internal variability of carbon fluxes. To be used for attribution of carbon-cycle variations (anthropogenic or natural) versus near-term scenarios with/without mitigation (NDCs).

Halving of probability in extremes date: an indication of when the likelihood of extreme seasonal warmth in an emission-mitigated world is half that of the same warmth in the unmitigated world.



Ciavarella et al. (2017, NCC)

Summary

- EC-Earth has been successfully used as a climate forecast system in the last few years. The differences with the ECMWF seasonal and sub-seasonal forecast systems have prevented a stronger collaboration.
- It has been used with issues like decadal prediction, generation of standards, multi-variate bias adjustment, observational uncertainty, bias-adjustment error propagation, user-driven research, etc.
- EC-Earth has also been analysed from a computational efficiency point of view and led to substantial improvements in NEMO.
- Coupled initialisation, extreme event attribution, increased resolution and the introduction of the carbon cycle are priorities for future development.
- The introduction of OpenIFS (post-CMIP6) offers a great opportunity for a closer relationship between EC-Earth and ECMWF.